



GUIDELINE FOR A SPATIAL MULTI-CRITERIA ANALYSES

Version n° 1 02/2022





Guideline for a spatial multi- criteria analyses

A.T3.3 Fostering the development of small renewable District Heating networks

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Reviewed by: **Steinbeis Transfer GmbH n° 4 - StT Solites**
Version date: **20.02.2022**
Version. Revision: **1.0**
Circulation: **PU - Public**

Document History

Date	Version	Description of Changes
20.02.2022	v 0.1	Document issued by PPn° 6

Partners involved



PPn° 4 - PP Steinbeis Transfer GmbH n° 4 - StT Solites



PPn° 6 - PP Energie Agentur Steiermark



Interreg CENTRAL EUROPE

Priority:	2. Cooperating on low-carbon strategies in CENTRAL EUROPE
Specific objective:	2.2 To improve territorial based low-carbon energy planning strategies and policies supporting climate change mitigation
Acronym:	ENTRAIN
Title:	Enhancing renewable heat planning for improving the air quality of communities
Index number:	CE1526
Lead Partner:	Ambiente Italia Ltd
Duration:	01.04.2019 31.03.2022





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1. (Spatial) Multi-Criteria Analysis

1.1. General

Multi-criteria analysis (MCA) generally refers to decision-making among several options or alternatives. The alternatives depend on several criteria, which can be weighted differently depending on the strength of influence on the result (see figure 1).

In the field of spatial energy planning spatial multi-criteria analyses can be applied in the site assessment for example solar thermal power plants and biomass power plants. This short document will be focused on these two types of power plants.

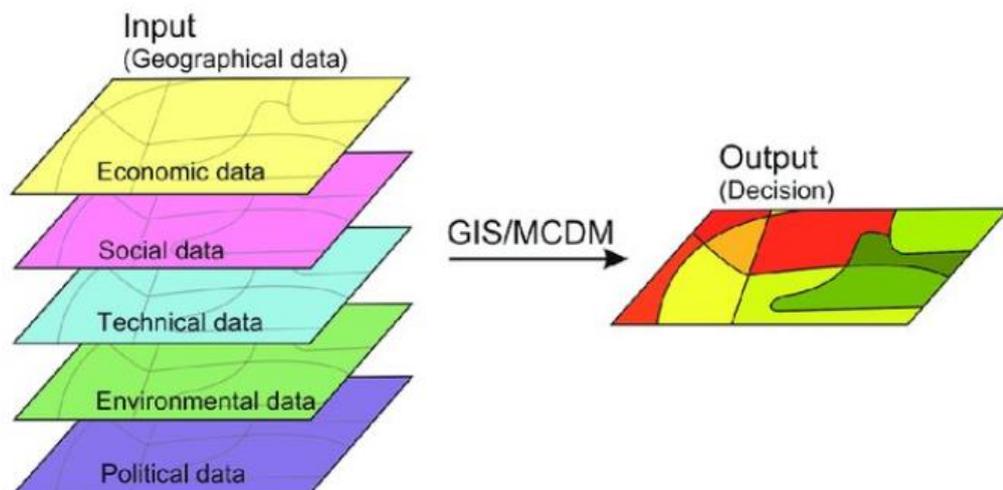


Figure 1: Schematic representation of the multi-criteria analysis, Source: Rikalovic, A., Cosic, I.: GIS based multi-criteria decision analysis for industrial site selection: The state of the art

1.2. Criteria

As written before to find the best alternative, multiple criteria can be involved. Depending on the object of the analysis, the chosen criteria can be completely different. In the field of MCA the criteria can be seen as different layers of geodata (see figure 1). The choice of the used criteria is very important. The planners should therefore take enough time to consider which criteria should be considered.

On the one hand, expert knowledge in the field of heat supply is essential (to cover the technical aspect), on the other hand, non-technical factors (e.g., visibility and disturbed residents) should also be included. Therefore, close coordination with the municipalities is also necessary.

Furthermore, it must be considered that corresponding (geo)data must also be available for each criterion. The criteria can have a value that positively influences the result (e.g., global radiation per m²), negatively influences it (e.g., distance to existing district heating line, inhabitants disturbed by noise) or is an exclusion criterion (protected area, forest area, a certain distance to the district heating network).



1.3. Weighting by pairwise comparison

As mentioned earlier, criteria can be weighted differently. These weightings can also include the subjective preferences of municipalities. For this purpose, there is the method of pairwise comparison. This involves comparing each criterion in pairs with all the other criteria. The simplest and quickest methodology is to simply ask which of the two comparing criteria is more important to one.

This pairwise comparison can be easily performed in Excel. For this purpose, the criteria are listed horizontally and vertically, so that a matrix is created. A suitable template (see figure 2) can be found under the following [link](#) (see figure 2).

An expert and/or a municipality only needs to fill in one half of the matrix with 0 or 1. The template then determines the percentage weighting based on the decision. It is advisable to have several experts and responsible persons in municipalities fill out this pairwise comparison and then average the result.

Pairwise Comparison

The cells highlighted with this color are automatically calculated

more important than	Criteria 1	Criteria 2	Criteria 3	Criteria 4	Criteria 5	Criteria 6	Criteria 7	Criteria 8	Criteria 9	Criteria 10	Sum	%
Criteria 1		1	1	1	1	1	1	1	1	1	9	20,00%
Criteria 2	0		1	1	1	1	0	0	1	1	6	13,33%
Criteria 3	0	0		1	1	0	0	1	1	1	5	11,11%
Criteria 4	0	0	0		1	0	0	0	1	1	3	6,67%
Criteria 5	0	0	0	0		1	0	1	1	1	4	8,89%
Criteria 6	0	0	1	1	0		1	1	1	1	6	13,33%
Criteria 7	0	1	1	1	1	0		1	1	1	7	15,56%
Criteria 8	0	1	0	1	0	0	0		1	1	4	8,89%
Criteria 9	0	0	0	0	0	0	0	0		0	0	0,00%
Criteria 10	0	0	0	0	0	0	0	0	1		1	2,22%
											Sum	100,00%

Figure 2: Template of the pairwise comparison tool in Excel, Source: www.sixsigmablackbelt.de



2. Applying this method in real cases

2.1. Define the criteria

In the research project ENTRAIN, this methodology was applied on a site assessment for a biomass heating plant and solar thermal ground-mounted plant. In the first step, criteria for both assessments were defined. The criteria can be seen in the following table. These criteria are calculated for each possible site. In this case, each parcel represents one possible site.

Biomass heating plant	Solar thermal ground-mounted plant
Buildings disturbed by delivery of wood	Annual solar radiation incident on the ground
Visibility of the heating plant from the buildings	Visibility of the solar thermal plant from the buildings
Average distance to the planned district heating network	Average distance to the planned district heating network
Ownership situation of the parcels	Ownership situation of the parcels
	Restriction layer for the planning of ground-mounted solar plants

It is important for the definition of criteria that they are also available as a geodata set or can be calculated from geodata, as in this case.

2.2. Acquisition of the geodata and calculation of the criteria

In the next step, the geodata sets required for the criteria must be acquired. For this purpose - depending on the required data - municipalities, heat network operators, regions, etc. must be contacted. If necessary, the required geodata must then be calculated from the input data.

In the case of the criteria defined above, the following data were acquired or calculated (in the brackets you find the sources of this dataset):

1. Biomass heating plant:

Biomass heating plant - criteria	Required data
Buildings disturbed by delivery of wood	<ul style="list-style-type: none"> - Building polygons (municipality or OpenStreetMap) - Road network (OpenStreetMap) with information where access by trucks is possible (municipality) - Parcels (municipality)
Visibility of the heating plant from the buildings	<ul style="list-style-type: none"> - Digital surface model (estimated from buildings and forest areas if not accessible) - Building polygons (OpenStreetMap) - Parcels (municipality)
Average distance to the planned district heating network	<ul style="list-style-type: none"> - Planned future district heating network (municipality) - Parcels (municipality)
Ownership situation of the parcels	<ul style="list-style-type: none"> - Parcels with information about municipal property (municipality)



2. Solar thermal ground-mounted plant

Solar thermal ground-mounted plant	Required data
Annual solar radiation incident on the ground	- Solar radiation (self-calculated) depended on the digital surface model
Visibility of the solar thermal plant from the buildings	- Digital surface model (estimated from buildings and forest areas) - Building polygons (OpenStreetMap) - Parcels (municipality)
Average distance to the planned district heating network	- Planned future district heating network (municipality) - Parcels (municipality)
Ownership situation of the parcels	- Parcels with information about municipal property (municipality)
Restriction layer for the planning of ground-mounted solar plants	- Restriction layer for the planning of solar thermal ground-mounted plants (municipality).

To compare the different criteria, the next step is to normalize all criteria values using the following formula:

$$z_{value} = \frac{x - \min(x)}{\max(x) - \min(x)}$$

x is the respective criterion value of each site, max(x) is the maximum value over all sites and min(x) is the minimum value over all sites. This formula must be applied for all criteria.

For better understanding, this formula is now applied to the following example:

There are six locations to be analyzed with their information about the distance to the nearest district heating network:

Location	Distance to district heating network [m]
Site 1	100
Site 2	300
Site 3	350
Site 4	400
Site 5	600
Site 6	850

Now for all sites the z-value will be calculated with the formula above. For example, here the formula for the second site:

$$z_{value} = \frac{300 - 100}{850 - 100} = 0,266$$



In the following table you find the results of the z-values for all sites:

Location	Distance to district heating network [m]	z-value
Site 1	100	0
Site 2	300	0,266
Site 3	350	0,333
Site 4	400	0,4
Site 5	600	0,666
Site 6	850	1

This procedure must be applied for all criteria.

2.3. Pairwise comparison

The next step is to ask experts for their opinion. In this practical example, this was done by municipality leaders. They simply compared the different criteria and rated them as 0 or 1. An example for the result is shown in figure 3.

Pairwise Comparison

The cells highlighted with this color are automatically calculated

than more important	Distance to DHS Network	Number of buildings from visibility analysis	Buildings negatively affected by supplying	Parcel owned by the municipality	Sum	%
Distance to DHS Network		0	1	0	1	2	20,00%
Number of buildings from visibility analysis	1		1	0	1	3	30,00%
Buildings negatively affected by supplying	0	0		0	1	1	10,00%
Parcel owned by the municipality	1	1	1		1	4	40,00%
.....	0	0	0	0		0	0,00%
						Sum	100,00%

Figure 3: Result of a pairwise comparison, Source of the template: www.sixsigmablackbelt.de

2.4. Calculation and visualization of the result

To obtain a result for all sites, the weights from the pairwise comparison are multiplied by the normalized values. This then results in a score of 0-1 for each site, the higher the score, the better. The corresponding formula is:

$$site_{evaluation} = z_{value_{criteria1}} * weight_{criteria1} + z_{value_{criteria2}} * weight_{criteria2} + \dots$$



The results can then be visualized as a map. The entire process is shown in the following figure:

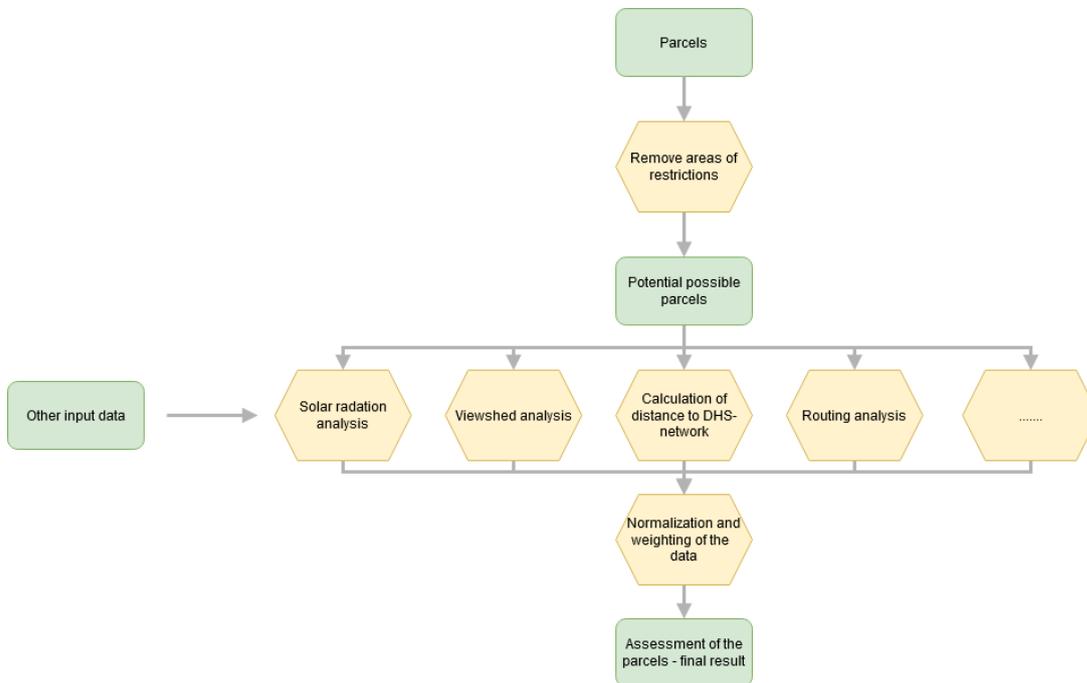


Figure 4: Process of the site assessment with Multi-Criteria Analysis



For all criteria maps can be created. Of course, the result can also be visualized as a map afterwards (see following figures).

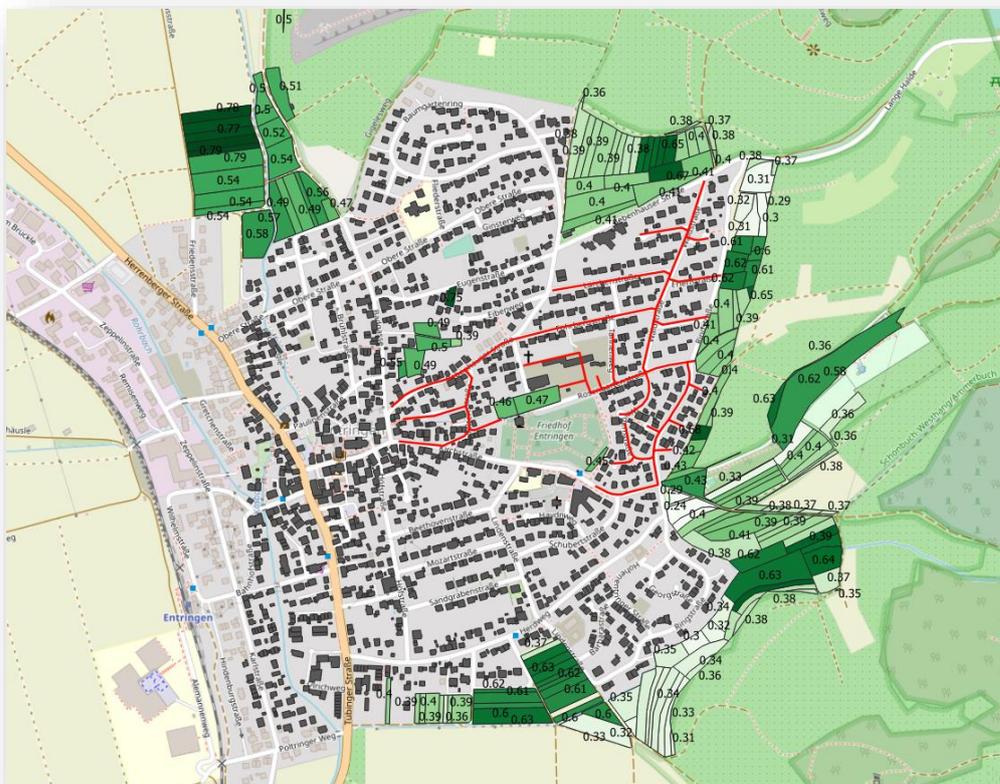


Figure 5: The results visualized as a map



3. Conclusion

In summary, this method is helpful for site assessments. There is the possibility to define own criteria and also to weight them according to importance.

The challenge clearly lies in the definition of the criteria. Namely, the criteria must be available as a data set. If necessary, the criteria must be calculated from other available data sets. Furthermore, it is important to define a catalogue of criteria, but also to set specific criteria locally in cooperation and collaboration with the planners, municipalities and residents.